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Optimisation of Tig Welding Parameters by using Taguchi's Approach - A Review

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Abstract: The objective of any industry is production of high quality products at low cost and increase the production rate. Welding is most important operation in any industry. It is essential to optimize the various parameters viz; welding current, welding speed, voltage, gas flow rate, etc. of welding process so that we can achieve the reliability, productivity and quality of the products. TIG welding process is versatile and commonly used operation for joining of two materials with the application of heat and /or pressure or filler material to increase the production with less time and cost. The purpose of this study is to describe different methods to decide near optimal settings of the welding process parameters in TIG welding. The properties of the welded joints such as tensile strength, impact force, hardness etc. are affected by different welding parameters.

Index Terms: GTAW, ANOVA, TIG welding, L16 orthogonal array,S/N ratio, GMAW.

1. Introduction: Welding is the process of joining two pieces of metal by creating a strong metallurgical bond between them by heating or pressure or both. A welded joint is obtained when two clean surfaces are brought into contact with each other and either pressure or heat, or both are applied to obtain a bond. The tendency of atoms to bond is the fundamental basis of welding. The basic equipment for TIG welding comprises a power source, a welding torch, a supply of an inert shield gas, a supply of filler wire and perhaps a water cooling system.

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Gas-tungsten arc welding (GTAW) is a process that melts and joins metals by heating them with an arc established between a non-consumable tungsten electrode and the metals. The tungsten electrode is normally contacted with a water cooled copper tube, which is connected to the welding cable to prevent overheating. The shielding gas (Ar, He) goes through the torch body and nozzle toward the weld pool to protect it from air. Filler metal (for joining of thicker materials) can be fed manually or automatically to the arc. It is also called tungsten inert gas (TIG) welding.

ELECTRODES: Tungsten electrodes with 2% cerium or thorium give better electron emissivity, current-carrying capacity, and resistance to contamination than pure electrodes. Hence, the arc is more stable.

SHIELDING GASES: Ar is heavier and offers more effective shielding and cheaper than He.

Working Principle of TIG Welding Operation:

TIG is an arc welding process, wherein coalescence is produced by heating the work piece with an electrical arc struck between a tungsten electrode and the job.

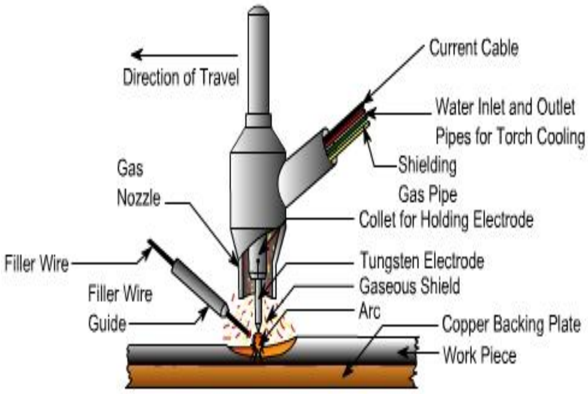

Fig.no.1

The electrical discharge generates a plasma arc between the electrode tip and the work piece to be welded. It is an arc welding process wherein coalescence is produced by heating the job with an electrical arc struck between a tungsten electrode and the job. The arc is normally initialized by a power source with a high frequency generator. This produces a small spark that provides the initial conducting path through the air for the low voltage welding current. The arc generates high-temperature of approximately 6100 C and melts the surface of base metal to form a molten pool. A welding gas (argon, helium, nitrogen etc.) is used to avoid atmospheric contamination of the molten weld pool. The shielding gas displaces the air and avoids the contact of oxygen and the nitrogen with the molten metal or hot tungsten electrode. As the molten metal cools, coalescence occurs and the parts are joined. The resulting weld is smooth and requires minimum finish.

ADVANTAGES:

[1] No flux is used, hence there is no danger of flux entrapment when welding refrigerator and air conditioner components.

[2] Because of clear visibility of the arc and the job, the operator can exercise a better control on the welding.

[3] This process can weld in all positions smooth and sound welds with fewer spatters.

[4] TIG welding is very much suitable for high quality welding of thin material.

[5] It is a very good process for welding nonferrous metals (aluminium) and stainless steel.

DISADVANTAGES:

[1] Tungsten if it transfers to molten weld pool can contaminate the same. Tungsten inclusion is hard and brittle.

[2] Filler rod end if it by change comes out of the inert gas shield can cause weld metal contamination.

[3] Equipment costs are higher than that for flux shielded metal are welding.

APPLICATIONS:

[1] Welding aluminium, magnesium ,copper ,nickel and their alloys, carbon, alloys or stainless steel, inconel ,high temperature and hard surfacing alloys like zirconium, titanium etc.

[2] Welding sheet metal and thinner sections.

[3] Welding of expansion bellows, transistor cases, instrument diaphragms, and can-sealing joints.

[4] Precision welding in atomic energy, aircraft, chemical and instrument industries.

[5] Rocket motor chamber fabrications in launch vehicles.

2. Literature Review:

Different researchers have discussed on effect of various welding parameters on mechanical strength of butt weld joint in various ways. They are summarized below.

S.D.Ambekar et al.[1] investigated the influence of welding parameters on the penetration. The optimization for Gas metal arc welding process parameters (GMAW) of Martensitic Stainless steel work piece AISI 410 using Taguchi method is done. Sixteen experimental runs

(L16) based on an orthogonal array Taguchi method were performed. They presented the effect of welding parameters like welding speed, welding current and wire diameter on penetration. AISI 410 Steel material plate is used, as it has a very large scale application in the process industry. Sample of 100mm×80mm×5mm size has been used as a work piece material and bead on welding is done A total of the three welding process parameters were chosen as the controlling factors. Each parameter was designed to have the four levels denoted by 1, 2 ,3 and 4 respectively. It is observed that by using Taguchi method analysis the optimum combination of the machine is found that A-4 , B-4 and C-4 i.e Welding speed = 60 cm/min , welding current = 110 amp and wire diameter = 1.2 mm. It is observed that the welding speed is most influencing factors and gas flow rate is least influencing factor.

V.Anand Rao et al.[2] analysed the mechanical properties and microstructure of 310 austenitic stainless steel welds are investigated, by using stainless steel filler material of different grades.310 austenitic Specimen of 50 x 50 x 3 mm dimension, were prepared and welded in butt joint configuration with single groove of 45OC groove angle. The root gap was kept at 1mm uniformly for all specimens. Welding current 120A and electrode 309L has produced greater tensile strength of 454.6MPa while a welding current 80A and electrode 316L has produced minimum tensile strength of 51.79MPa for the specimen studied. In bend test the welding current with 120A and electrode 316L has produced maximum bending strength of 646.55MPa while the same welding current with electrode 347 has produced minimum bending strength of 211.37MPa for the specimen studied. The filler material 309L has produced better tensile and bending strength. The ultrasonic test results showed defects of penetration, but in general results indicate that the defect does not create much impact.

Q.Wang et al.[3] studied the influences of parameters of tungsten inert gas arc welding on the morphology, microstructure, tensile property and fracture of welded joints of Ni-base super alloy. Results show that the increase of welding current and the decrease of welding speed bring about the large amount of heat input in the welding pool and the enlargement of width and deepness of the welding pool. Materials for experiments are plates of Ni-base super alloy, grade GH99, with a thickness of 1.2 mm and 1.5 mm respectively. Welding parameters selected were welding current 55~165A, welding speed 19~29cm/mm, impulse frequency 2~5Hz. The heat input increases with the decrease of welding speed and the increase of welding current. The optimized processes are number 5, 14 and 23, i.e. the welding current is 80~90A, the welding speed is 25 cm/min, the impulse frequency is 3Hz.

P. Bharath et al.[4] analysed the influence of various welding parameters on the weld bead of AISI 316 welded joint. They studied the influence of various input parameters on the tensile strength and bending strength of AISI 316 welded joint. The influence of speed, current, electrode, root gap is identified by ANOVA method. Taguchi method is used to find first optimal parameters by using L27 (35) orthogonal array. L27 (35) means that it will investigate for 3 levels and 5 factors on qualitative index for each factor. The parameters influencing tensile strength and bending strength were found out by using ANOVA technique. A three point bend test and tensile test for the specimen are performed on UTM. The bending strength increases as the root gap between the specimens varies. The tensile strength of the specimen varies with the speed of the welding. The speed increases within the range of the root gap, which in turn increases the better tensile strength. Current, speed, root gap has some influence on the tensile strength and the bending strength of the material. Based on Analysis of variance (ANOVA) it is found that welding speed (46.51% contribution) has greater influence on bend strength and current (96.75%) has highest influence on tensile strength. Further it is found that root gaps has some influence on both tensile and bend strengths.

Navid Moslemi et al.[5] optimised 316 stainless steel pipes with outside diameter is 73mm and 7.0mm thickness using Tungsten Inert Gas (TIG) welding process. 316 stainless steel pipe with diameter of 73mm and 7.0mm thickness was cut using power saw and turned on the lathe machine to prepare the V surface with the angle of 37.5º ±2.5º. The V type for butt joint was chosen with the root face was 0.5mm. TIG welding process was carried out manually. The increase of welding current bring about the large amount of heat input in the welding pool, the enlargement of width and deepness of the welding pool, cumulative sigma phase in the matrix and reducing the chromium carbide percentage in 316 stainless steel welded joint. Arc current of 100A has been identified of the most suitable current since it gives the lowest defects and brings the highest value of strength and hardness for this material. The heat input rises with the increase of welding current. It can induce the widening and deepening of the welding pool. Moreover, it can cause that the strength of welded joints goes up first and then falls down.

Ajit Khatter et al.[6] proposed a method to decide near optimal settings of the welding process parameters in TIG welding. The properties of the welded joints are affected by a large number of welding parameters. Properties include Tensile strength, Impact force, Hardness etc. Material used is stainless steel 304. Plates of 300 mm x 20 mm x 8mm are welded along their long edge. The use of the L9 orthogonal array, with three control parameters is used with a sample of 18 work pieces. Optimum parameter setting for weld strength is obtained at current of 150 amps, 28 volt, and 14-litre/min-gas flow.

Ugur Esme et al.[7] investigated the multi-response optimization of tungsten inert gas welding (TIG) welding process for an optimal parametric combination to yield favourable bead geometry of welded joints using the Grey relational analysis and Taguchi method. The Taguchi approach followed by Grey relational analysis to solve the multi-response optimization problem. The significance of the factors on overall quality characteristics of the weldment has also been evaluated quantitatively by the analysis of variance method (ANOVA). They applied a Taguchi L16 (44) orthogonal array to plan the experiments on TIG welding process. Weld beads were laid on the joint to join 1.2 mm AISI 304 thin stainless steel plate with the dimensions of (25 × 240) mm. Experimental results have shown that the tensile load, heat affected zone and penetration, area of penetration, heat affected zone, bead width and bead height of the weld bead in the TIG welding of stainless steel are greatly improved by using Grey relation analysis in combination with Taguchi method.

Shekhar Rajendra Gulwade et al.[8] discussed the influence of welding parameters like welding current, welding voltage and gas flow rate on hardness of austenitic stainless steel on 304 grade material during welding. A plan of experiments based on Taguchi technique has been used to acquire the data, an orthogonal array and signal to noise (S/N) ratio are employed to investigate the welding characteristics of butt joint and optimize the welding parameters. To find out percentage contribution of each input parameter for obtaining optimal conditions, we were used analysis of variance (ANOVA) method. The work material used for work is austenitic stainless steel the dimensions of the work piece length 100mm, width 75mm, thickness 0.5mm. Argon is used as a shielding gas. A Taguchi orthogonal array, the signal-to-noise (S/N) ratio and analysis of variance were used for optimization of welding parameters. A conformation experiment was also conducted and verified the effectiveness of the Taguchi optimization method. The improvement of S/N ratio is 0.04. The experiment value that is observed from optimal welding parameters, the Hardness is 188.70 BHN & S/N ratio is 45.51.

Dinesh Kumar.R et al.[9] described the optimization of process parameters like current, voltage, stand-off distance, pulse on time, pulse off time and weld speed, gas flow to improve weld quality. In this work Taguchi method is used to get the optimal parameters. In Taguchi method, L27 orthogonal array is used for experimentation. Weld speed and input current are found to be the most significant parameters. The strength of the weld is validated by tensile and bending test. A thin sheet of 304L Stainless Steel was used for experimentation with length 150 mm, width 40mm and thickness 1.6 mm. The trials are made on the 2mm plate designed by Taguchi model L27 Orthogonal array with 3 factor 3 level design and corresponding depth of penetration for each trial is calculated by means of Welding Expert system. The optimum values obtained from the selected factors for welding of 1.6mm plate are Speed 125mm/min, Current 125 A, Stand-off 2mm, Frequency 3 Hz, Gas flow 10 litre/min. The most important parameters affecting the responses have been identified as speed and current.

J.Pasupathy et al.[10] experimented the influence of welding parameters like welding current, welding speed on strength of low carbon steel on AA1050 material during welding. A plan of experiments based on Taguchi technique has been used to acquire the data. An Orthogonal array, signal to noise (S/N) ratio and analysis of variance (ANOVA) are employed to investigate the welding characteristics of dissimilar joint and optimize the welding parameters. Finally the conformations tests have been carried out to compare the predicted values with the experimental values to confirm its effectiveness in the analysis of strength. Low carbon steel of 1mm thickness and 2mm thick AA1050 aluminium alloy are used. The dimensions of the work piece, length 300 mm, width 150mm. A Taguchi orthogonal array, the signal-to-noise (S/N) ratio and analysis of variance were used for the optimization of welding parameters. A con-formation experiment was also conducted and verified for the effectiveness of the Taguchi optimization method. The experiment value that is observed from optimal welding parameters, the strength is 61.37MPa. & S/N ratio is 16.45.

Abhishek Prakash et al.[11] investigated on Taguchi approach [L9], using Analysis of variance (ANOVA) to determine the influence of parameters with the optimal condition. They experimented mainly focussing on the weldability of low carbon steel ASTM A29 with the process of TIG welding. The work details of process parameters (welding voltage, welding current and wire speed) influence on the response (Tensile strength and Hardness) by using analysis of variance (ANOVA) with the help of Taguchi array [L9]. The dimension of work sample is length 200 mm, width 100 mm, thickness 80 mm. The optimal conditional for Tensile strength as the welding current (230) is a dominant parameter on the tested specimens, followed by welding voltage (18) and wire speed (2.2). The optimal condition of Hardness, such as the welding voltage (18 volts), welding current (215 amp), and wire speed (2.2) can be used to achieve better hardness in ASTM A29.

G. Magudeeswaran et al.[12] explained the shape of a weld in terms of its width-to-depth ratio known as aspect ratio and has a marked influence on its solidification cracking tendency. The major influencing ATIG welding parameters, such as electrode gap, travel speed, current and voltage, that aid in controlling the aspect ratio of DSS joints, must be optimized to obtain desirable aspect ratio for DSS joints. Hence in this study, the above parameters of ATIG welding for aspect ratio of ASTM/UNS S32205 DSS welds are optimized by using Taguchi orthogonal array (OA) experimental design and other statistical tools such as Analysis of Variance (ANOVA) and Pooled ANOVA techniques. The optimum process parameters are found to be 1 mm electrode gap, 130 mm/min travel speed, 140 A current and 12 V voltage. The electrode gap is the predominant factor that affects the aspect ratio of DSS welds fabricated using ATIG welding process.The optimum welding parameters are found to be electrode gap of 1 mm, travel speed of 130 mm/min, current of 140 A, and voltage of 12 V.

A.Sivasankaran et al.[13] analysed the improvement of ultimate tensile strength of Aluminium 8011 weld specimen made of tungsten inert gas welding. A plan of experiments based on Taguchi method has been used. L16 orthogonal array has been used to conduct the experiments at different levels of welding parameters like pulse current, peak current, pulse frequency and pulse duty cycle. Signal-to-noise ratio (S/N ratio), analysis of variance (ANOVA) and graphical mean effect plots for S/N ratio are employed to investigate the optimal level of process parameters and influence of welding parameters on weld strength. The work material used for present work is Aluminium 8011. The dimensions of the work piece are: length 100 mm, width 25 mm and thickness 6 mm. Confirmation experiment was also conducted and the effectiveness of Taguchi optimization method was verified. The experimental value of ultimate tensile strength that is observed from optimal level of welding parameters is 155.682 N/mm2. The improvement in S/N ratio is 0.894.

Arun Kumar Srirangan et al.[14] focused on the multi-objective optimization using grey relational analysis for Incoloy 800HTwelded with tungsten inert arc welding process with N82 filler wire of diameter 1.2mm. The welding input parameters play a vital role in determining desired weld quality. The experiments were conducted according to L9 orthogonal array. The input parameter chosen were the welding current, Voltage and welding speed. The output response for quality targets chosen were the ultimate tensile strength , yield strength and impact toughness. Grey relational analysis was applied to optimize the input parameters simultaneously considering multiple output variables. The optimal parameters combination was determined as welding current at 110 A, voltage at 10 V and welding speed at 1.5 mm/s.

Arivarasu.M et al.[15] described the optimization of process parameters for pulsed current gas tungsten arc welded austenitic stainless steel AISI 304L of 4 mm thickness. Four plates of dimensions (200 mm × 100 mm × 4 mm) were cut from rolled plate. In HF pulsing the Peak % ON time is the factor which has most influence on the bead geometry while in low frequency pulsing the frequency (Hz) influences the most.

Conclusion: The present paper give a study of optimization on the parameters on TIG welding. From the literature, it is observed that there are lot of work done for parameters like current, voltage, gas flow and speed to find out the tensile strength, hardness and heat effected zone. From above papers study some conclusions derived are given below.

1.Different parameters (different gas, electrode diameters, different compositions of filler rods) of process can be taken for welding 316 stainless steel with Taguchi and ANOVA method.

2.The effects of parameters on impact strength of butt weld joint on different grove angles has been calculated.

3.The best suitable parameters for maximum tensile strength, fatigue strength, hardness and heat effected zone are found out.

4.The Taguchi approach has been built on traditional design of experimental methods to improve the design of products and processes.

5.The interactions of current and voltage greatly influences the tensile strength of the material.

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